CLAIMS

1. A lithographic projection apparatus comprising:

a radiation system constructed and arranged to supply a projection beam of radiation;

a support structure constructed and arranged to support beam patterning structure, the beam patterning structure serving to pattern the projection beam according to a desired pattern;

a substrate table constructed and arranged to hold a substrate;

a projection system constructed and arranged to project the patterned beam onto a target portion of the substrate; and

an alignment system to align the substrate to the beam patterning structure,

said alignment system comprising:

an excitation source for directing electromagnetic radiation to a surface of said substrate so as to induce a wave therein in a region of an at least partially buried substrate alignment mark; and

a measurement system to direct a measurement beam to be reflected by said surface and to detect surface effects caused by said wave thereby to perform an alignment to said substrate alignment mark.

2. Apparatus according to claim 1, wherein:

said excitation system is arranged to induce waves in said substrate at a plurality of points; and

said measurement system is arranged to detect surface effects at said plurality of points to generate thickness data relating to thickness of at least one layer covering said

substrate alignment mark and to correct an alignment process carried out using a surface pattern induced by said substrate alignment mark.

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3. Apparatus according to claim 1, wherein said excitation source is a laser constructed and arranged to emit pulses shorter than 1 nanosecond to induce an acoustic wave in at least one covering layer obscuring said substrate alignment mark.

4. Apparatus according to claim 3, wherein said excitation source is arranged to irradiate a measurement area with two temporally coincident overlapping excitation pulses having mutually different angles of incidence, thereby to induce a standing acoustic wave pattern in the surface of said substrate; and said measurement beam is to be diffracted by said standing wave pattern and the measurement system detects the time-dependent diffraction of said measurement beam.

5. Apparatus according to claim 3, wherein said excitation source is arranged to irradiate a measurement area with an excitation pulse or pulse train so as to generate an acoustic travelling wave propagating into said substrate; and said measurement system further comprises a measurement beam source to direct a measurement beam to be reflected by the surface of said substrate and a detector for detecting time-dependent surface effects of said surface of said substrate caused by returning echoes of said travelling wave.

6. Apparatus according to claim 3 wherein said excitation source is arranged to irradiate said region so as to induce an acoustic travelling wave in at least one covering layer obscuring said substrate alignment mark so as to be selectively reflected by said substrate alignment mark; and said alignment system further comprises an alignment beam source to

direct an alignment beam to be diffracted by images of said substrate alignment mark formed in the surface of said covering layer by returning echoes of said substrate alignment mark.

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~~7. Apparatus according to claim 1, wherein said excitation source is a modulated continuous wave source which is constructed and arranged to emit a harmonically varying beam of radiation so as to induce a thermal wave in the at least one covering layer obscuring said substrate alignment mark.~~

8. Apparatus according to claim 7, wherein said wave source is a continuous wave laser.

9. Apparatus according to claim 7, wherein said wave source is modulated with a frequency lower than 10 MHz.

10. Apparatus according to claim 1, wherein said measurement system is constructed and arranged to measure changes in reflection of the surface of said wafer caused by waves induced by the excitation source.

11. Apparatus according to claim 1, wherein said measurement system is constructed and arranged to measure displacements of the surface of said wafer caused by waves induced by the excitation source.

12. Apparatus according to claim 1, wherein the support structure comprises a mask table to hold a mask.

13. Apparatus according to claim 1 wherein the radiation system comprises a radiation source.

14. A method for determining a position of a substrate alignment mark, comprising:

inducing a wave in at least one surface layer of a substrate at least partially covering the substrate alignment mark;

measuring surface effects of the surface of said substrate where said wave has been induced; and

determining the position of said substrate alignment mark using the results of said measuring said surface effects.

15. A method according to claim 14 wherein said inducing a wave and said measuring the surface effects are repeated at a plurality of positions in the region of said substrate alignment mark so as to generate a map of the thickness of at least one layer covering said substrate alignment mark and said map is used in said step of determining the position of said substrate alignment mark.

16. A device manufacturing method comprising:

providing a substrate provided with an alignment mark that is at least partially covered by a layer of radiation sensitive material;

projecting a patterned beam of radiation onto a target portion of the layer of radiation-sensitive material; and

determining a position of a substrate alignment mark, comprising:

inducing a wave in at least one surface layer of a substrate at least partially covering the substrate alignment mark;

measuring surface effects of the surface of said substrate where said wave has been induced; and

determining the position of said substrate alignment mark using the results of said measuring said surface effects.

17. A device manufactured according to the method of claim 16.

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